Biodegradability of Selected EDCs Under Redox Conditions Typical of Wastewater Treatment and Sediments

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Purpose

A number of emerging chemicals being detected in the environment are now gaining attention for having possible endocrine disrupting capabilities. These endocrine disrupting chemicals (EDCs) have been shown to have adverse affects on the endocrine system of fish and wildlife. But not much information is known about the fate of EDCs in the environment, particularly in the anaerobic environment. This research looks specifically at the biodegradability of nonylphenol (NP) and estogenic hormones under redox conditions typically found in wastewater treatment and sediments through the use of respirometers and microcosms.

Science Questions

1. What are the major sources and environmental fates of EDCs?
2. How can unreasonable risks be managed?

Background

NPs are commonly used in the production of alkylphenol (AP)-based surfactants and find their way into the environment through their intended uses as detergents, chemical additives, deicers, etc. Most commonly, alkylphenols are introduced into wastewater collection and treatment systems, where some treatment may occur. The ethoxylates are removed during aerobic treatment, with the end product of NP. As a result, NP can be discharged to the environment and due to its hydrophobic nature, will commonly partition to sediments.

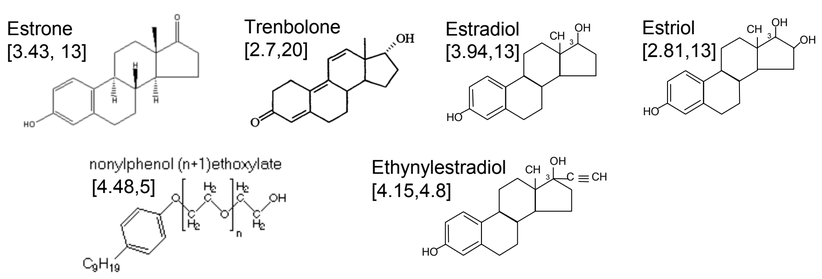
Estrogenic hormones are excreted from the body in a conjugated form and often become deconjugated while moving to a treatment system or early in the waste treatment process. Different types of wastewater treatment can have varying levels of removal efficiencies, with the estrogenic hormones entering the environment, primarily though wastewater treatment effluent. Once in the environment, estrogenic hormones are somewhat hydrophobic and will partition to the sediments.

Approach

Five Redox Conditions Evaluated

- Aerobic
- Nitrate reducing
- Sulfate reducing
- Methanogenic
- Iron reducing

Target Compounds for Research



*[Log Kow, water solubility (mg/L)]

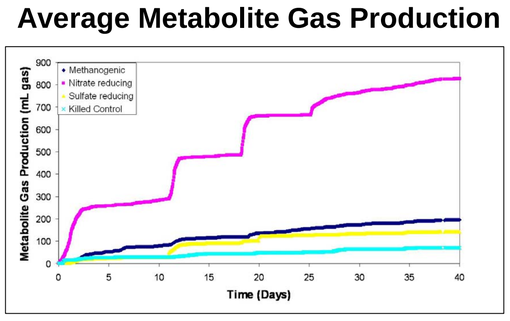
Enrichment Cultures in Respirometers

- Culture enrichment through successive dilutions and feedings of target compounds to develop a culture utilizing the target compounds as the sole carbon source.
- Samples for the inocula obtained from wastewater treatment plant activated sludge for aerobic bioderadation and from wastewater treatment plant anaerobic digesters and sediments for anaerobic biodegradation.
- Develop a culture of degraders from a vast mixture of microorganisms to determine the maximum degradation rates under ideal conditions.
- Provides a positive control for microcosm studies.

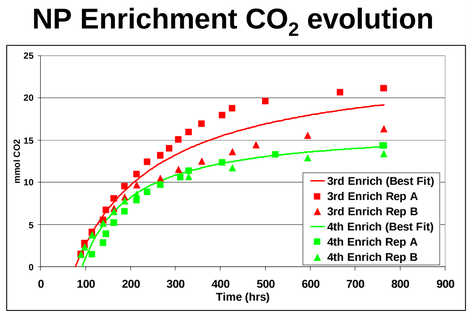
Microcosms

- Aerobic and anaerobic single treatment, batch reactors sampled at various time points.
- Sacrificial sampling to remove sampling bias.
- Utilizes inoculua from domestic and industial wastewater treatment operations and sediment downstream of wastewater outfalls.

Average Metabolite Gas Production



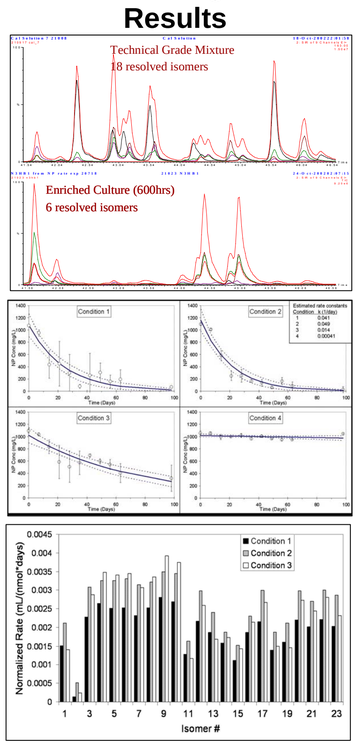
NP Enrichment CO_2 evolution



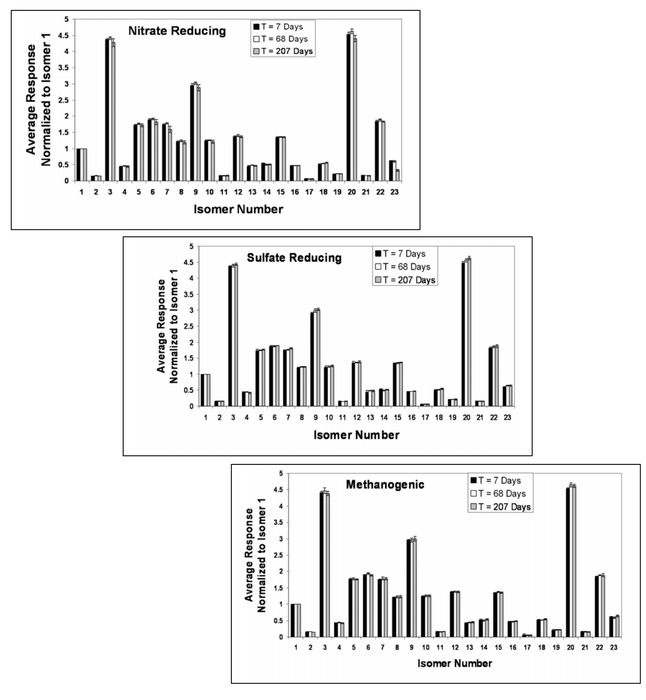
Project Status

- Nonylphenol
  - ✓ NP was characterized using GC-MS for 23 isomers over time in microcosms and using aerobic and anaerobic respirometers.
  - ✓ Under aerobic conditions, NP is relatively rapidly biodegraded with a typical half-life of 15-20 days but has a low cell yield (0.25 g-biomass/g-NP).
  - ✓ Under anaerobic conditions, no biodegradation was observed in over 100 days of exposure.
- Hormones
  - ✓ Analytical methods have been developed.
  - ✓ Enrichment cultures and microcosms are being developed.

Aerobic Biodegradation Results



Anaerobic Biodegradation Results



Conclusions

- Statistically significant difference in the biodegradation rates of the isomers with the most estrogenic isomers degrading faster.
- Comparisons between known isomer structures and biodegradation rates show that correlations exist between the branching of the alkyl chain and biodegradability.
- The less estrogenic isomers are the more recalcitrant isomers.
- Under the three anaerobic conditions examined, NP degradation using cultures from anaerobic digester of a local wastewater treatment plant did not occur.
- This may explain the high levels of NP found in anaerobic digesters and the persistance of NP in sediments.
- Additional research will be conducted to look at the biodegradability of a suite of hormones; Estrone, 17β-Estradiol, 17α-Ethynylestradiol, Estriol, and Trenbolone.

Future Research

The results of this project will be used to design research to identify the sources and the fate of EDCs in the environment. This will be expanded to include the following:

- Conduct field scale evaluations of the fate of selected EDCs in full-scale treatment operations and in-stream sediments.
- Determine the treatment capability of on-site wastewater treatment systems for EDCs
- Expand the list of target EDC compounds.

Impact and Outcomes

Understanding the fundamental degradability of these compounds will add in improved designs for wastewater treatment unit operations to better manage the risk of EDCs. The results of this research can be used to help WWT operators understand the capability of their plants to remove EDCs, how process variables influence performance, and how to improve the operation of their plants to minimize effluent levels of EDCs.